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Original Research Article

Sand amended with carbonised rice husk and goat manure as a propagation medium

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Abstract

Tomato is an important horticultural crop as it provides income and contributes to food security for Rwandan citizens. Besides its importance, its production is hampered by the use of a soil-based growing medium which results in the production of low-quality transplants. This is mainly attributed to the unaffordability of peat moss to small-scale farmers in Rwanda. Hence, a greenhouse nursery experiment was carried out at the Rwanda-Israel Horticulture Centre of Excellence to search for an alternative growing medium to peat moss. Nine different growing media were formulated from a mixture at different ratios of sand, goat manure, and carbonised rice husks. The seeds were sown in propagation trays. The experiment was laid out in a randomised complete block design (RCBD) with four replications. Data obtained were subjected to analysis of variance and means were separated using Tukey's honestly significant difference test at $p \leq 0.05$. The data analysis was carried out using SAS software version 9.2. The results revealed that sand + goat manure + carbonised rice husk 50%: 10%: 40% (T8) was comparable to T1 (peat moss 100%) in producing higher quality seedlings during both trials with a mean quality index of 0.28 and 0.31, respectively, whereas T2 (sand 100%) had seedlings with the poorest quality. Consequently, T8 can be adopted by nursery producers as an alternative to peat moss in the production of quality tomato transplants. More research on other locally available organic substrates is encouraged to find out alternatives to expensive media like peat moss because it was observed that the use of sand + goat manure + carbonised rice husk 50%: 10%: 40% revealed in production of quality seedlings with no significant difference from the ones grown in peat moss.

Keywords: Top soils; peat moss; growing medium; carbonisation; nursery; tomato; sowing; seedling emergence; growth; **t**ransplants; seedling quality; Dickson quality index

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is a solanaceous vegetable grown worldwide (Sharma and Singh, 2015). It originated from the Andean zone but its first cultivation was in Mexico (Uddain et al., 2009). It is the second most consumed vegetable in the world after potato (FAOStat, 2020). Tomato fruits are consumed fresh or processed and are used for soup, pickles, ketchup, puree, sauces, and as a salad vegetable (Shereni et al., 2015).

Tomato is considered a major vegetable in Rwanda as it is the second most produced vegetable in volume and area cultivated after cabbage and the first in cash value (ACED, 2011). The production of tomatoes has increased by almost 300% since 2008 in Rwanda (Niek et al., 2017). Although tomato production has increased, it is still constrained by the high cost of inputs, limited skills, rain-fed based production due to limited irrigation systems, high cost of protected cultivation (Arah, 2015), diseases, insects, and mite pests which are dominant in the tropical regions and postharvest problems (Srinivasan, 2010), and the use of traditional methods whereby the seedlings are produced using natural soils as growing medium (Patil et al., 2017).

The production of healthy and vigorous tomato seedlings is the most important factor in the successful production and yield of tomatoes. The germination of the seed is a critical stage because the rest of the plant life is directly dependent upon the rate of its germination (Gama et al., 2015). Healthy tomato seedling production ensures early maturity and high yield in the field while crop uniformity is also maintained (Ndayambaje, 2010). A yield increase of 27% was obtained for tomatoes whose seedlings were grown in nurseries as transplants when compared to conventional agriculture (Markovic et al., 1996).

The production of quality tomato seedlings is hampered by the traditional methods of raising seedlings using garden soil. This method requires many seeds which increases the cost of seed material and is associated with a high incidence of pests and diseases, a high rate of mortality, and non-uniform growth of seedlings leading to the production of low-quality seedlings (Patil et al., 2017). The method is becoming unpopular because the soils are associated with an imbalance of microorganisms, water, and air, nutrition, variability and weeds leading to seedling stress. In addition, after transplanting, the plants need a long period for roots to continue their normal growth and development (Landis et al., 1990). In addition, this method leads to reduced productivity, soil erosion, reduced soil fauna, and other forms of degradation due to frequent digging for medium collection (Baiyeri, 2006).

Peat moss is the organic substrate that is mostly used as a growing medium for diverse plant production. It has physical and chemical characteristics which include porosity of >9%, air capacity of 15–40%, water availability of 25–30%, pH of 3–5, electrical conductivity (EC) of 0.20–0.60 mS/cm, ashes of 1–6%, cation exchange capacity (CEC) of 100–170 meq/100g and C: N ratio of 30/8. These properties make it to be the main substrate component for seedling production in containers (Aendekerk, 2000). Despite its tremendous advantage, it is an expensive material for farmers (Abdel-Razzak et al., 2019). Peat is non-renewable and environmentally unfriendly as it degrades very slowly and simultaneously emits the bound carbon as CO_2 which contributes to greenhouse gas (Raviv, 2013). Consequently, it is important to search for alternative growing media to peat moss.

Carbonised rice husk (CRH) is a light material with a micro-porous structure and bulk density of about 0.150 g/cm^3 (Haefele et al., 2009). It improves soil properties by increasing available phosphorus, improving aeration in the crop root zone, water-holding capacity, and rising levels of exchangeable K and Mg and it is a major source of organic carbon (Haefele et al., 2009). Its good physical properties positively affect moisture relations and airflow to the crop as well as anchorage and supply of nutrients (Kumah, 2011). In addition, carbonised rice husk influences emergence and seedling vigour with a consequent effect on the quality of seedlings produced (Baiyeri, 2003).

Goat manure improves the physical condition of the soil and provides the required plant nutrients (Uwah and Eyo, 2014). A study by Ojeniyi et al. (2019) reported that the application of goat manures improved organic matter (OM). Furthermore, the use of goat manure as organic fertiliser enhanced the mobility of P, K, and micronutrients and facilitates microbial activities, and increases the N, P, K, Ca, and Mg status of soil (Ojeniyi and Adegboyega, 2003). More importantly, Ghorbani et al. (2008) stated that these manures are not expensive, environmentally friendly, and protect the health of humans as well as the ecosystem.

Medium to coarse sand (0.2–2 mm diameter) has been found to be a good substrate because it increases aeration, drainage, and bulk density (Gungoran and Yildirim, 2013) and reduces the acidity of the growing medium leading to good nutrients uptake by roots and better growth of the plant (Parasana et al., 2013). The current study was conducted in two trials and investigated the emergence, growth, and quality of tomato seedlings as affected by different growing media formulated from the mixture of different ratios of sand, goat manure and carbonised rice husks.

MATERIALS AND METHODS

Description of the experimental site

The research was conducted at the Rwanda-Israel Horticulture Centre of Excellence located at Rwanda Agriculture and Animal Resources Development Board, Mulindi Station/ Kigali city. It is in Runyonza village, Nyagahinga Cell, Rusororo Sector, Gasabo District of Kigali city, on the longitude of 30°16′876″E, the latitude of 02°00′417″S and at an altitude of 1340 m above sea level (GPS coordinates).

Carbonised rice husk (CRH) preparation

Carbonisation of the rice husks was done outdoors with the following materials: a holed tin of 10L volume and metal chimney of 25 cm diameter, firewood, shovel, water, watering can, candle, and a box of matches. The firewood was filled in the tin and a chimney was fixed on the top of the tin. The fire was set on the woods inside the tin, and the rice husks were piled around the tin until half of the chimney was covered. As the rice husks next to the tin were turning black, they were frequently turned over to prevent them from completely burning to ash until all were carbonised. After carbonisation, water was immediately sprinkled over the entire pile to avoid continuous burning (Sarian, 2008). Thereafter, the CRH was broken into pieces to reduce its size while increasing the chance of water and nutrient-holding capacity.

Preparation of peat moss, topsoil, sand and goat manure

Peatmoss was purchased from Holland Greentech-Rwanda. Goat manure was prepared from goat droppings. They were collected from loafing shed located around the Rwanda-Israel Horticulture Centre of Excellence (HCoE). Thereafter, they were air-dried until a constant weight was reached and then ground using a mortar. The sand was collected from Rusine River and sieved using a 2 mm sieve to get medium to coarse sand. Thereafter, the obtained sand was washed to flush out any salt content and then air-dried to remove the remaining water. The top layer of soil of about 5–20 cm (Ahmed et al., 2016) was collected from a field located around the experimental site using the diagonal sampling method to obtain a composite sample. Thereafter, it was air-dried for one week and then subjected to sterilisation (Nkurunziza et al., 2022).

Formulation and characterisation of growing media

The substrates: carbonised rice husks, goat manure, topsoil, sand, and peat moss were applied either singly or in combination at different ratios to formulate a growing medium with the optimum level for better growth of tomato transplants. The formulated growing media were peat moss 100 % (T1), sand 100 % (T2), top soil + goat manure 70 %: 30 % (T3), sand + goat manure 50 %: 50 % (T4), sand + goat manure + carbonised rice husk 50 %: 40 %: 10 % (T5), sand + goat manure + carbonised rice husk 50 %: 30 %: 20 % (T6), sand + goat manure + carbonised rice husk 50 %: 20 %: 30 % (T7), sand + goat manure + carbonized rice husk 50 %: 10 %: 40 % (T8) and sand + goat manure + carbonised rice husk 50 %: 0 %: 50 % (T9). All the growing media were sterilised by drying them in an oven at 120 °C for 2 days. Thereafter, they were analysed in the laboratory for their physical and chemical properties (Nkurunziza et al., 2022).

Physical characterisation

Bulk density was determined by inserting into the medium a 5 cm diameter thin-sheet metal tube of known weight (W1) and volume (V) of 5cm^3. The medium was excavated around the tube and the medium beneath the tube bottom was cut. Excess medium substrates from the tube ends were removed using a knife and then dried at 105 °C for 2 days and weighed to get W2. Bulk density was calculated using the formula (g/cm3) = (W2 g – W1 g)/V (cm^3) as described by Anderson and Ingram (1993). The total porosity was measured using the formula:

$$Po = 1 - (qb/qs)$$

where *q*b and *q*s are bulky density and particle density in percentage, respectively (Baruah and Barthakur, 1998).

Chemical characterisation

The pH was measured on 2.5:1 soil water suspension while EC of the saturated paste extract was measured to determine the level of salinity as described by Okalebo et al. (2002). Total nitrogen was calculated using the formula:

$$\%\,N \text{ in soil sample} = (A - B) \times 0.1 \times v \times 100/1000 \times W \times al$$

where A = volume of the titre HCl for the blank, B = volume of the titre HCl for the sample, V = final volume of the digestion, W = weight of the sample taken, and al = aliquot of the solution taken for analysis (Okalebo et al., 2002).

Total phosphorus was determined using ascorbic acid as described by Okalebo et al. (2002) with the following formula:

$$P \text{ in sample } (\%) = C \times V \times f/W$$

where C = the corrected concentration of P in the sample, V = volume of the digest, f = dilution factor, W = weight of the sample.

The potassium content of the growing medium was determined using the procedure of flame photometry as described by Okalebo et al. (2002).

Organic matter (OM) was calculated after ash content determination using the formula:

$$\text{ash } (\%) = [(W3 - W1) / (W2 - W1)] \times 100 \text{ and organic matter } (\%) = 100 - \text{ash}\%$$

Table 1. Physical and chemical characterisation (Means ± SD) of different formulated growing media (Nkurunziza et al., 2022)

Treatment.	pH Water	EC (mS/cm)	K (meq/100 g)	Tot. P (Ppm)	B. D. (g/cm^3)	Tot. N (%)	OM (%)	OC (%)	Porosity (%)
T1	5.8 ± 0.21	0.33 ± 0.03	7.18 ± 0.03	600 ± 4.54	0.09 ± 0.02	0.18 ± 0.02	89.70 ± 0.42	52.03 ± 0.53	90.00 ± 2.16
T2	6.8 ± 0.28	0.19 ± 0.01	0.26 ± 0.02	6.20 ± 0.21	1.53 ± 0.02	0.00 ± 0.00	0.48 ± 0.05	0.27 ± 0.02	42.42 ± 0.66
T3	6.9 ± 0.21	3.92 ± 0.18	2.82 ± 0.24	55.5 ± 2.94	1.08 ± 0.05	0.06 ± 0.02	26.66 ± 0.25	15.46 ± 0.57	59.26 ± 1.46
T4	6.7 ± 0.21	4.78 ± 0.16	4.36 ± 0.34	376.5 ± 3.62	1.16 ± 0.04	0.04 ± 0.01	27.2 ± 1.31	15.78 ± 0.49	56.28 ± 2.81
T5	6.7 ± 0.43	2.39 ± 0.34	3.85 ± 0.36	216.00 ± 0.71	1.08 ± 0.08	0.16 ± 0.05	13.16 ± 0.63	7.63 ± 0.94	61.45 ± 1.03
T6	6.6 ± 0.14	3.34 ± 0.24	3.08 ± 0.12	302.5 ± 3.19	1.10 ± 0.18	0.06 ± 0.03	7.74 ± 0.30	4.49 ± 0.10	48.49 ± 1.08
T7	6.8 ± 0.18	3.04 ± 0.27	2.31 ± 0.20	302.5 ± 1.18	1.09 ± 0.02	0.13 ± 0.04	7.88 ± 0.19	4.57 ± 0.37	58.85 ± 1.05
T8	6.5 ± 0.18	1.86 ± 0.13	2.05 ± 0.06	302.5 ± 1.15	1.17 ± 0.05	0.11 ± 0.03	7.57 ± 0.42	4.39 ± 0.26	55.96 ± 0.87
T9	6.8 ± 0.21a	0.71 ± 0.11	1.28 ± 0.04	166.7 ± 1.24	1.16 ± 0.06	0.19 ± 0.04	6.77 ± 0.16	3.93 ± 0.18	56.32 ± 0.48

T1: Peat moss 100%, T2: Sand 100%, T3: Top soil + Goat manure 70%: 30%, T4: Sand + Goat manure 50%: 50%, T5: Sand + Goat manure + Carbonised rice husk 50%: 40%: 10%, T6: Sand + Goat manure + Carbonised rice husk 50%: 30%: 20%, T7: Sand + Goat manure + Carbonised rice husk 50%: 20%: 30%, T8: Sand + Goat manure + Carbonised rice husk 50%: 10%: 40% and T9: Sand + Goat manure + Carbonised rice husk50%:0%:50%.

where W1 = the weight of the empty, dry crucible containing growing medium, W2 = the weight of the dry crucible containing growing medium, and W3 = the weight of the dry crucible containing growing medium following ignition. W3 – W1 = weight of the ash (Okalebo et al., 2002). The organic carbon (OC) was calculated using the formula; OC (%) = T × 0.2 × 0.3/sample weight (g) where T is the titre (Okalebo et al., 2002). The obtained results are presented in the table below:

Planting Material

Tomato 'Shanty + PM' (Powdery Mildew resistant) seeds were used as a test crop. The variety is a semi-determinate saladette fruit type and is cultivated in both open fields and a greenhouse for all planting seasons. The plants are vigorous and produce firm fruits with attractive red colour and oval shapes weighing from 100–150 g. The seeds were purchased from Hazera-Rwanda, Kigali.

Experimental design and treatment application

The study evaluated nine treatments in a randomised complete block design with four replications. Each treatment was assigned to four cells of a propagation tray representing a single plot. The treatments used in this study were; peat moss 100% (T1), sand 100% (T2), top soil + goat manure 70%: 30% (T3), sand + goat manure 50%: 50% (T4), sand + goat manure + carbonised rice husk 50%: 40%: 10% (T5), sand + goat manure + carbonised rice husk 50%: 30%: 20% (T6), sand + goat manure + carbonised rice husk 50%: 20%: 30% (T7), sand + goat manure + carbonised rice husk 50%: 10%: 40% (T8) and sand + goat manure + carbonised rice husk 50%: 0%: 50% (T9).

Sowing of tomato seeds

For trial one, tomato seeds were sown on 5th January 2020 and transplanted on 4th February 2020 and those for the second trial were sown on 15th March 2020 and transplanted on 13th April 2020. Seeding was performed by placing one seed in each cell of the propagation tray with a volume of 50 cm^3. The seeds were sown at a depth of 0.5 cm and 64 seeds were applied per treatment for each trial translating to 576 seeds. After sowing, the trays were placed on beds in the nursery greenhouse. Irrigation was done twice per day, the first in the morning and another, in the afternoon.

Determination of seedling emergence and growth

Seedling emergence was recorded 10 days after sowing; the number of emerged seedlings was counted from each experimental unit and then recorded in percentage using the formula:

$$\text{Emergence (\%)} = (\text{Seeds emerged/ Total number of seeds sown}) \times 100$$

Seedling growth parameters were evaluated 30 days after sowing using 16 seedlings per experimental unit. The number of leaves (NL) was recorded and seedling height (SH) was measured from the base of the stem to the apex of the last leaf using a ruler. Stem diameter (SD) was measured slightly above the root collar using a vernier caliper and then its size was measured using a ruler. Root length was determined by placing a ruler from the tallest root tip of the seedling to the root collar.

Determination of seedling quality

In the calculation of the development quality index (IQD), the method of Dickson et al. (1960) was used considering the dry mass of shoots, roots, and total dry mass, height, and diameter of the lap of the seedlings using the formula:

$$IQD = \frac{PMST}{\frac{AP}{DC} + \frac{PMSPA}{PMSR}}$$

where IQD = Dickson development index, PMST = total dry mass (g), AP = plant height (cm), DC = lap diameter (mm), PMSPA = dry weight of aerial part (g), and PMSRA = root dry mass weight (g).

Fresh shoot mass (MFPA) and roots (MFR) were obtained by separating the seedlings into aerial parts and roots. Afterward, the roots were washed in water; the parts were placed together and identified according to the treatment and taken for air drying until the constant weight is reached. Analytical balance with a precision of 0.001 g was used to weigh the dry mass of the aerial (MSPA) and roots (MSR) parts.

Data analysis

The general linear model (GLM) was used to determine whether the studied parameters of the formulated growing media were significantly different. Tukey's honestly significant difference (HSD) test was used to separate significantly different treatment means. These analyses were performed using the Statistical Analysis Software package, SAS software version 9.2 at a 5% level of significance (SAS Institute, 2010). The model fitted for this experiment was:

$$y_{ijk} = \mu + T_i + \beta_j + \varepsilon_{ijk}$$

where Y_{ijk} = Overall observations, μ = Overall mean, T_i = Effect due to ith treatment, β_k = Effect due to kth block, and ε_{ijk} = Random error term, i: 1, 2, 3, 4, 5, 6, 7, 8 and 9 and j: 1, 2, 3 and 4.

RESULTS

Seedling emergence

The treatments significantly ($p \leq 0.05$) influenced seedling emergence from ten days after sowing (DAS). The plots treated with peat moss had the highest number of emerged seedlings followed by the ones containing carbonised rice husks and goat manure ratios. The sand alone and topsoil plus goat manure recorded significantly lower seedling emergence (%) than peat moss, the positive control in both trials 1 and 2. The treatments had a slightly high average number of emerged seedlings (90.97%) in trial one compared to 89.57% in trial two.

Number of leaves

Different growing media significantly influenced the number of leaves per seedling at 10 DAS in both trials with an average of 3.31 and 3.28 leaves in trials one and two, respectively. Generally, the plots treated with carbonised rice husks were comparable to peat moss in recording a high number of leaves in trial one. However,

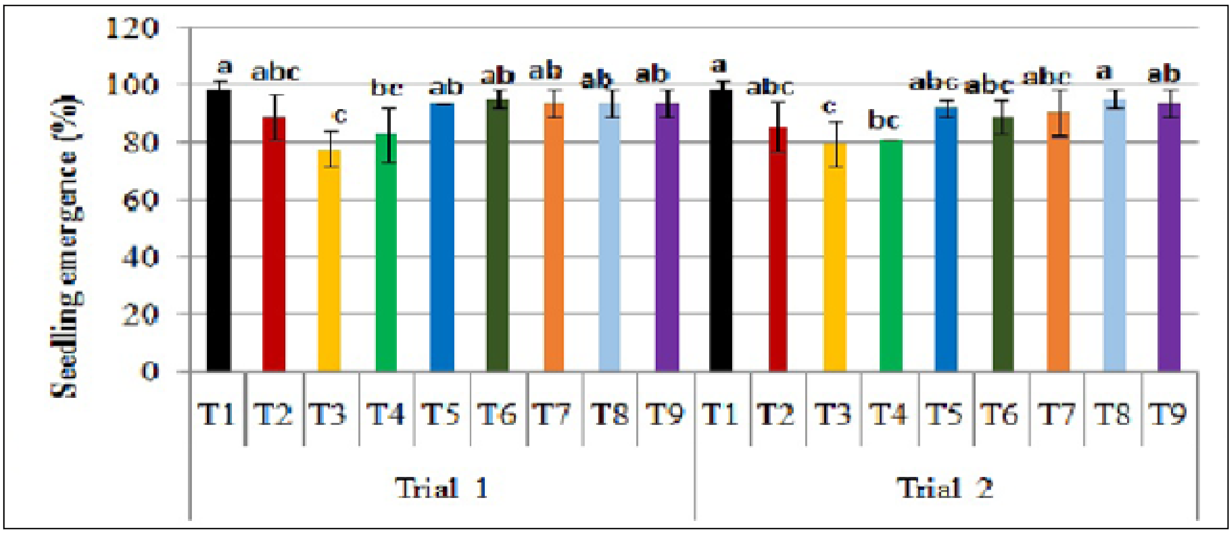

Figure 1. Seedling emergence (%) of tomato var. Shanty + PM grown in different growing media in trials one and two.
T1: Peat moss 100%, T2: Sand 100%, T3: Top soil + Goat manure 70%: 30%, T4: Sand + Goat manure 50%: 50%, T5: Sand + Goat manure + Carbonised rice husks 50%: 40%: 10%, T6: Sand + Goat manure + Carbonised rice husks 50%: 30%: 20%, T7: Sand + Goat manure + Carbonised rice husks 50%: 20%: 30%, T8: Sand + Goat manure + Carbonised rice husks 50%: 10%: 40% and T9: Sand + Goat manure + Carbonised rice husks 50%: 0%: 50%. Different letters above the bars indicate significant differences according to Tukey's test ($p \leq 0.05$).

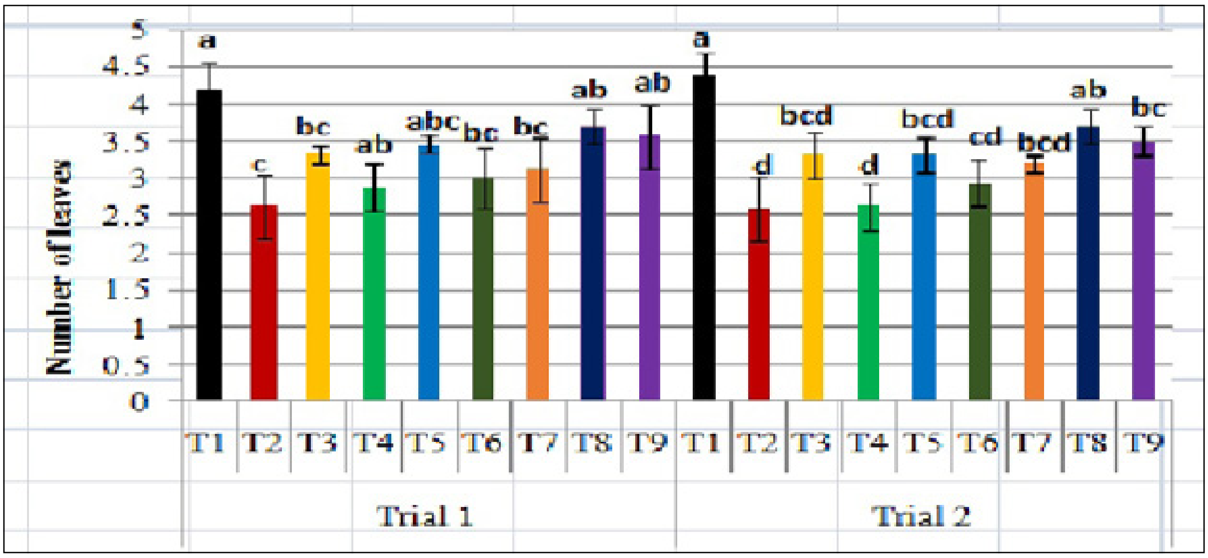

Figure 2. The number of leaves of tomato seedlings var. Shanty + PM grown in different growing media in trials one and two.

T1: Peat moss 100%, T2: Sand 100%, T3: Top soil + Goat manure 70%: 30%, T4: Sand + Goat manure 50%: 50%, T5: Sand + Goat manure + Carbonised rice husks 50%: 40%: 10%, T6: Sand + Goat manure + Carbonised rice husk 50%: 30%: 20%, T7: Sand+ Goat manure + Carbonised rice husks 50%: 20%: 30%, T8: Sand + Goat manure + Carbonised rice husks 50%: 10%: 40% and T9: Sand + Goat manure + Carbonised rice husks 50%: 0%: 50%. Different letters above the bars indicate significant differences according to Tukey's test ($p \leq 0.05$).

in trial 2, only T8: Sand + Goat manure + Carbonised rice husk 50%: 10%: 40% was similar to peat moss in the number of leaves per seedling.

Seedling height

The treatments significantly influenced the seedling heights at 10 DAS in both trials one and two. The tallest seedlings were generally observed in plots treated with carbonised rice husks, which were comparable to 100% peat moss, the positive control.

Root length

Trial two recorded a high average root length of 6.85 cm compared to the 6.76 cm of trial one. Both trials revealed a significant difference among the treatments where seedlings grown in T1 had the longest roots while the shortest ones were observed in T2 and T3. In both trials,

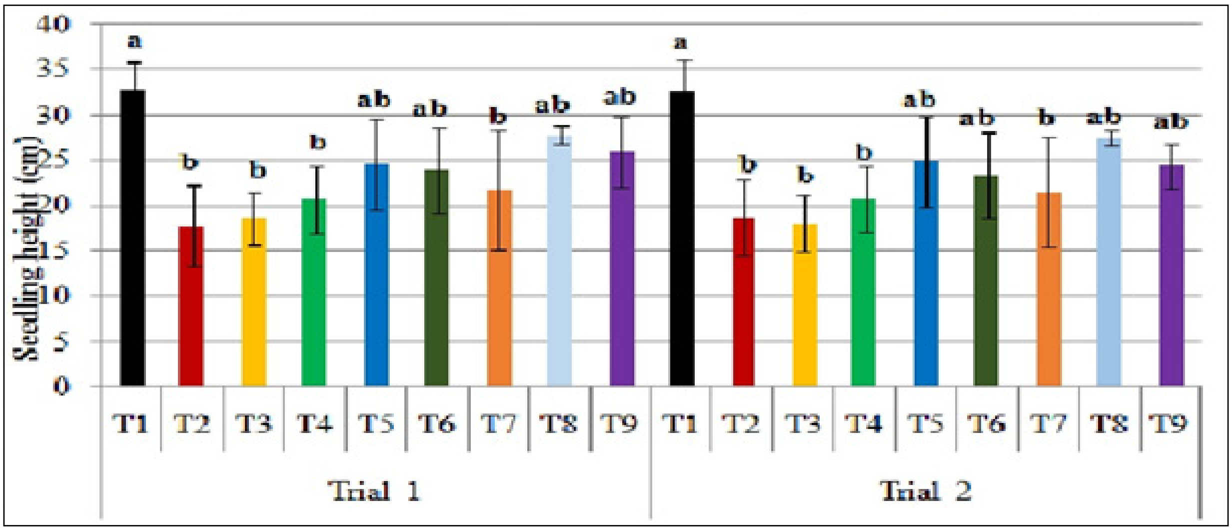

Figure 3. Seedling height of tomato var. Shanty + PM grown from different growing media in trials one and two.

T1: Peat moss 100%, T2: Sand 100%, T3: Top soil + Goat manure 70%: 30%, T4: Sand + Goat manure 50%: 50%, T5: Sand + Goat manure + Carbonised rice husks 50%: 40%: 10%, T6: Sand + Goat manure + Carbonised rice husks 50%: 30%: 20%, T7: Sand + Goat manure + Carbonised rice husks 50%: 20%: 30%, T8: Sand + Goat manure + Carbonised rice husks 50%: 10%: 40% and T9: Sand + Goat manure + Carbonised rice husks 50%: 0%: 50%. Different letters above the bars indicate significant differences according to Tukey's test ($p \leq 0.05$).

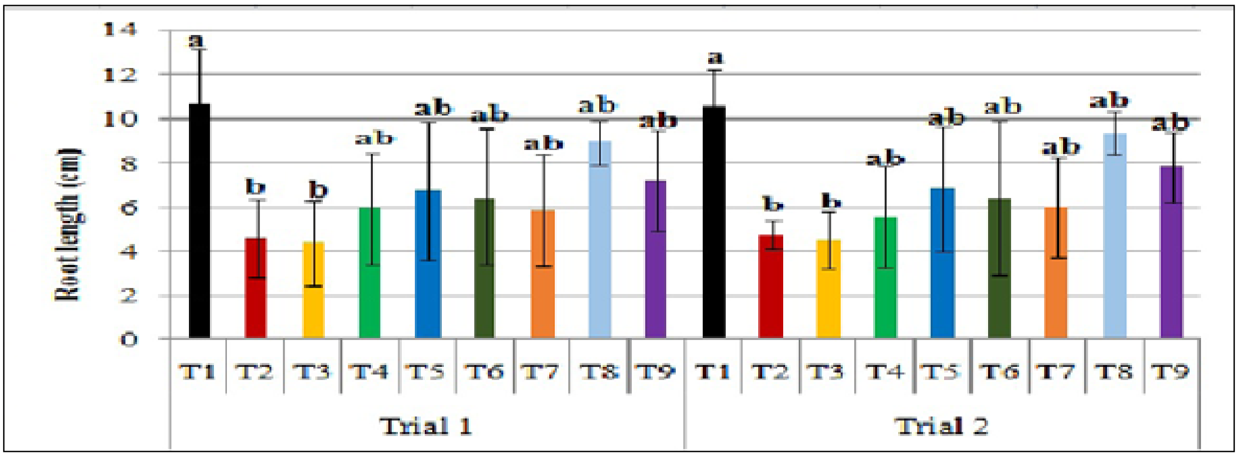

Figure 4. Root length of tomato seedlings var. Shanty + PM grown in different growing media in trials one and two.

T1: Peat moss 100%, T2: Sand 100%, T3: Top soil + Goat manure 70%: 30%, T4: Sand + Goat manure 50%: 50%, T5: Sand + Goat manure + Carbonised rice husks 50%: 40%: 10%, T6: Sand + Goat manure + Carbonised rice husks 50%: 30%: 20%, T7: Sand + Goat manure + Carbonised rice husks 50%: 20%: 30%, T8: Sand + Goat manure + Carbonised rice husks 50%: 10%: 40% and T9: Sand+ Goat manure + Carbonised rice husks 50%: 0%: 50%. Different letters above the bars indicate significant differences according to Tukey's test ($p \leq 0.05$).

the plots treated with different carbonised rice husks ratios generally were similar to peat moss in recording significantly longer roots than plots treated with sand, topsoil and goat manure.

Stem collar diameter

The propagation media significantly influenced ($p \leq 0.05$) seedling collar diameter in both trials whereby the plots treated with carbonised rice husks and peat moss continued to record high values compared to other plots. The highest average collar diameter was found in trial one at 0.29 cm while trial two had 0.28 cm. The plots treated with high levels of carbonised rice husks (40%–50%) were similar to peat moss in consistently exhibiting higher value of collar diameter than the other plots in both trials.

Seedling quality

During this study, the treatments displayed a significant difference in seedling quality. The plots treated with carbonised rice husks and goat manure were comparable to those treated with peat moss recording the highest seedling quality indices in both trials. Sand (100%) resulted in the lowest seedling quality index in both trials 1 and 2.

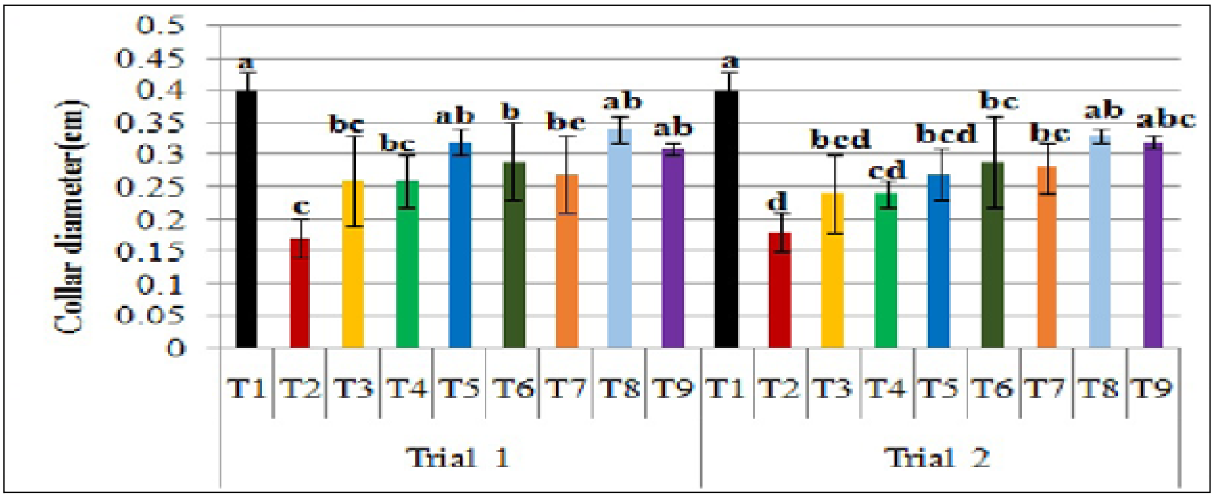

Figure 5. Stem collar diameter of tomato seedlings var. Shanty + PM grown from different growing media in trials one and two.

T1: Peat moss 100%, T2: Sand 100%, T3: Top soil + Goat manure 70%: 30%, T4: Sand + Goat manure 50%: 50%, T5: Sand + Goat manure + Carbonised rice husks 50%: 40%: 10%, T6: Sand + Goat manure + Carbonised rice husks 50%: 30%: 20%, T7: Sand + Goat manure + Carbonised rice husks 50%: 20%: 30%, T8: Sand+ Goat manure + Carbonised rice husks 50%: 10%: 40% and T9: Sand + Goat manure + Carbonised rice husks 50%: 0%: 50%. Different letters above the bars indicate significant differences according to Tukey's test ($p \leq 0.05$).

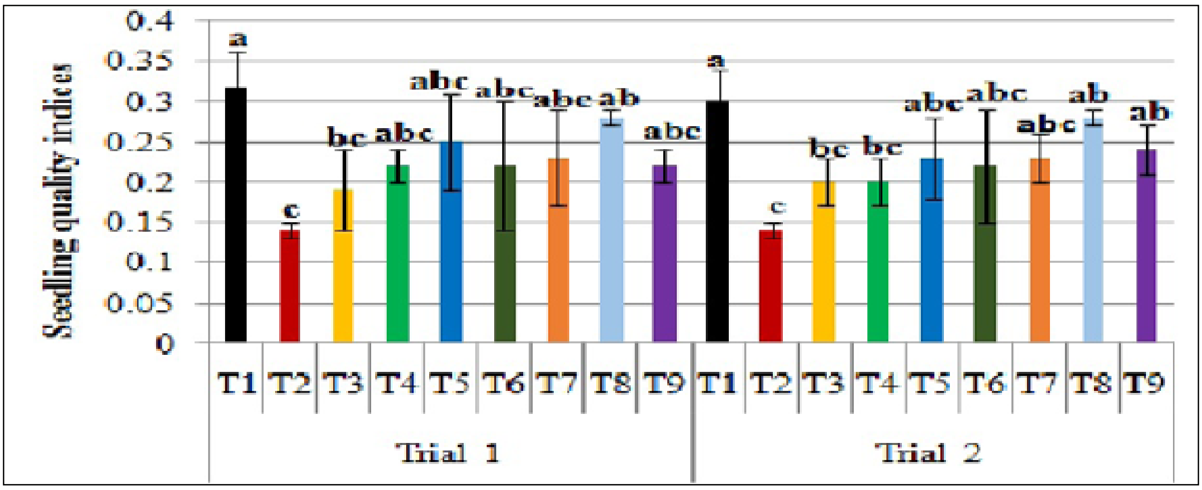

Figure 6. Seedling quality indices of tomato var. Shanty + PM grown in different growing media in trials one and two.

T1: Peat moss 100%, T2: Sand 100%, T3: Top soil + Goat manure 70%: 30%, T4: Sand + Goat manure 50%: 50%, T5: Sand + Goat manure + Carbonised rice husks 50%: 40%: 10%, T6: Sand + Goat manure + Carbonised rice husks 50%: 30%: 20%, T7: Sand + Goat manure + Carbonised rice husks 50%: 20%: 30%, T8: Sand + Goat manure + Carbonised rice husks 50%: 10%: 40% and T9: Sand + Goat manure + Carbonised rice husks 50%: 0%: 50%. Different letters above the bars indicate significant differences according to Tukey's test ($p \leq 0.05$).

DISCUSSION

The highest seedling emergence values observed in this study could be attributed to porosity, nutrient holding capacity, and EC (Table 1), especially of growing media with peat moss and high ratios CRH (40 and 50%v/v). Porosity improves the aeration and water-holding capacity of the medium (Melo et al., 2019). Water retention favours the imbibition process by absorbing water through colloids of the dry seed coat and hydrates protoplasm which further activates the synthesis of enzymes enhancing other biochemical processes responsible for seed germination and seedling emergence (Abdel-Razzak et al., 2019). However, the seedling emergence was reduced in the treatments with high levels of EC. This observation is supported by Sánchez-Monedero et al. (2004) who indicated that there was a delay in germination and emergence of tomato seeds due to the increase in EC beyond 3.5 mS/cm. However, Al-Harbi et al. (2008) stated that germination reduced with EC concentration beyond 2.39 ms/cm because salinity facilitates the intake of toxic ions which make changes in different enzymatic and hormonal activities and decrease water absorption. On the other hand, the plots treated with sand alone recorded the lowest emergence percentage which could be attributed to a low concentration of nutrients such as phosphorus and high pH of 6.8 which was beyond the value recommended for tomato seedling production of between 6.0 and 6.5 (Madziwa, 2014).

The best seedling growth was obtained in T8 and T9 which were not significantly different from T1, the positive control in most cases during both trials. Bulk density affects plant growth mainly through the effects of reduced free pore space as its increase is linked to the decrease in total pore space, oxygen transport, and root penetration (Sabahy et al., 2015). In addition, Raviv and Lieth (2008) reported that porosity influences plant growth because an increase in porosity decreases water retention, enhances oxygen transport, and increases root penetration in a growing medium. Organic matter is a source of food for plants as it improves water-holding capacity by binding the medium particles in aggregates, nutrient supply and acts as food for soil microorganisms (Hijbeek, 2017). On the other hand, poor growth performance obtained in T2, T3, and T4 may be due to the fact that T2 presented poor physical and chemical properties which are responsible for plant growth while T3 and T4 had high EC which contribute to reduced growth (Zhang et al., 2016). Though T5 presented good physical and chemical properties, it recorded low values of growth parameters compared to T1, T8, and T9 which could be attributed to low phosphorus content and EC. The superior performance of T8 and T9 can be attributed to high ratios of CRH which improved porosity, increased available phosphorus, water-holding capacity, and high levels of exchangeable K and Mg and organic carbon in the formulated growing media (Haefele et al., 2009). In addition, the soil-based media have low hydraulic properties as the plant root gets higher water availability just after irrigation which causes lower oxygen content to be used by root and microflora (Asaduzzaman et al., 2015). In addition, soils have low root development and nutrient absorption capacity which may negatively affect plant growth (Bar-Tal, 1999).

Peat moss influences seedling growth due to its high capacity to hold water, superior organic matter, and nitrogen and phosphorus contents which together favour plant growth (Atif et al., 2016). In addition, it has good porosity and aeration features (Papamichalaki et al., 2014). The treatments with mixtures of goat manure have significantly influenced seedling growth parameters since the goat manure provided essential elements required for plant growth. The growing medium released the required nutrients such as nitrogen, phosphorus, potassium, magnesium, and calcium with general concentrations of 2.2–3.4, 0.3–0.7, 1.5–2.5, 0.4–0.8 and 1.5–2.4, respectively, and increased the organic matter content in the medium (Azeez and Averbeke, 2010). Similar results were obtained in the research done by Mowa et al. (2017) who reported that goat manure enhanced tomato height and stem thickness. Good growth parameters observed in growing media treated with CRH may be due to the fact that CRH increased total organic carbon, total N, and available P and K, Ca, Mg and other microelements needed for growing crops (Haefele et al., 2011). In addition, they refill the air and retain water in the soil, and are free from pathogens, and are a tremendous host for beneficial microorganisms (Nierras, 2019). These results concur with the ones observed in the research by Nierras (2019) who found that the ratio between 30–50%v/v CRH resulted in the highest tomato height. However, a ratio of 75–100% CRH in a growing medium indicated no improved influence on the growth parameters of lettuce (Freitas et al., 2013).

Seedling height, seedling vigour, and dry matter accumulation percentage and quality increased due to higher phosphorus content which is involved in the formation of energy-rich compounds favouring biochemical reactions in the plant leading to better growth (Atif et al. 2016). In addition, phosphorus is required for strong root development and disease resistance during early growth stages and in all metabolism processes in a tomato seedling which include photosynthesis and respiration (Madziwa, 2014). Nitrogen helps in the production of good leaf and stem development since it is most required in the synthesis of amino acids, chlorophyll, proteins, coenzymes, and nucleic acids (Cunfer, 2004). Potassium on the other hand is responsible for the transport of sugars and stomata control which regulates photosynthesis as well as the transport of cofactors of many enzymes. It plays an important role in carbohydrate metabolism and enhances water use efficiency in tomato seedlings resulting in the regulation of transpiration rate by stomata. Furthermore, it delays the senescence of seedling leaves thus supporting canopy cover for photosynthesis, promoting growth, and improving disease resistance in tomato seedlings (Grubinger, 2017). However, the decrease in the concentration of K, N, and P and low porosity results in reduced growth performance of tomato seedlings resulting in weaker plants and weight loss (Grubinger, 2017).

CONCLUSION AND RECOMMENDATIONS

The studied formulated growing media significantly influenced the emergence, growth, and quality of tomato seedlings. The use of different mixtures of sand, goat manure, and carbonised rice husks with ratios of 50%: 40%: 10% (T5), 50%: 30%: 20% (T6), 50%: 20%: 30% (T7), 50%: 10%: 40% (T8), and 50%: 0%: 50% (T9) revealed in the production of tomato transplants with good quality indices with no significant difference from the seedlings grown in peat moss alone. The best values of germination and growth parameters of seedlings were obtained with peat moss alone and T8. Therefore, T8 can be utilised to optimise the germination rates and healthy growth of greenhouse tomato seedlings. This treatment can be used as an alternative to peat moss in tomato seedling production, which is being exhausted in natural resources. More research on locally available organic substrates to find out other cheap and affordable propagation media which can replace peat moss as an expensive and unaffordable medium to farmers. The results of this study will help nursery producers to select the best growing medium as an alternative to peat moss which can result in the production of high-quality tomato transplants.

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CONFLICT OF INTEREST

The authors declared no conflicts of interest with respect to the research, authorship, and publication of this article.

ETHICAL COMPLIANCE

The authors have followed ethical standards in conducting the research and preparing the manuscript.

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